Estimation of Pull-Out Forces of an Artificial Hip Joint with Preventing Structure from Dislocation

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Introduction. Total hip arthroplasty (THA) is an effective treatment for osteoarthritic patients (1). THA is a surgical procedure that the painful osteoarthritic hip joint is replaced with artificial components. In THA, diseased human hip joint is replaced using an artificial hip joint. A number of scientific and clinical studies have been performed to develop the effective treatments. However, there are still various problems with the artificial hip joint. For example, joint dislocation frequently occurs due to the weakness of muscles surrounding the hip joint. In order to prevent the dislocation, the movement or activity is limited in the patients with the artificial hip joint. Therefore, this limitation is a reason why an ideal rehabilitation cannot be conducted after the joint replacement surgery. In the present study, we newly proposed an artificial hip joint which has the structure to prevent joint dislocation. Pull-out forces of the joint were estimated using a finite element method. Specifically, the effects of outer shell thickness on the pull-out forces were determined by contact stress analysis. From the results, we understood the characteristic of the joint to prevent the dislocation and suggested a concept of its optimal design.

Methods. We proposed a novel type of artificial hip joint with a preventing structure from joint dislocation. Its acetabular cup has a shape with over the half of sphere as illustrated in Fig. 1. Due to this geometric configuration, the joint dislocation does not easily occur in the artificial hip joint. Three dimensional model of one part in twelve equal parts of femoral head and acetabular cup in the artificial hip joint was built using computer-aided design software. Femoral head diameter was set at 6 mm. The inner and outer shell thickness of the acetabular cup was 1 and 2 mm, respectively. Finite element models were constructed to estimate the pull-out forces of the joint using finite element analysis software (ANSYS). The outer parts of the cup and femoral head were made of titanium alloy (Ti-6Al-4V), and the inner part of the cup was made of ultra-high molecular weight polyethylene (UHMWPE). Behavior of these materials was represented with a linear isotropic elastic material model. The bottom area of the outer shell of acetabular cup was fully restrained. The femoral head was vertically pulled out from the acetabular cup and the pull-out displacement was set at 2 mm. The maximum outer thickness was 1.0 mm. Then, we removed the parts of the outer shell and thinned dawn the shell to construct the model with the thin outer part. The thickness of the outer shell after the removal was 0, 0.1, 0.2, 0.3, 0.4, 0.5, and 0.6 mm. The pull-out forces were determined for each model of the artificial hip joint.

Results and Discussion. Figure 2 shows the relationship between the outer shell thickness and pull-out forces in the artificial hip joint model without the slit. There was a clear reduction in the force with decrease in the outer shell thickness. In particular, a remarkable decrease in the force was observed in the case of the outer shell less than 0.1 mm in thickness. The pull-out force was 41.6 and 27.3 N in the case of the outer shell of 1.0 and 0.1 mm in thickness, respectively. Therefore, we can say that the outer shell made of titanium alloy plays an important role to prevent the dislocation of the artificial hip joint.

References.
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